THE LAST DAYS OF THE STEAM-ENGINE.

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" The introduction of new Inventions seemeth to be the very chief of all human Actions. The Benefits of new Inventions may extend to all Mankind universally; but the Good of political Achievements can respect but some particular Cantons o f Men; these latter do not endure above a few Ages, the former forever. Inventions make all Men happy, without either Injury or Damage to any one single Person. Furthermore, new Inventions are, as it were, new Erections and Imitations of God's own Works."—LORD BACON.

" . . . Was I wrong in predicting that the heat-engine of the future will probably be one independent of the vapor of water ?"—SIR FREDERICK BRAMWELL.

RECENT advances in the improvement of the various forms of heat-engines other than the steam-engine, and the assumed or apparent slow progress of the latter prime motor during recent years, have led many men of science, no less than many a charlatan or other less well-informed ordinary mortal, to question whether the last days of the steam-engine are not approaching; whether the grand invention of James Watt, his predecessors, his successors, and his joint inheritors of fame among inventors, may not be on the eve of passing away with the countless other antiquated inventions of the past centuries. This anticipation of an early disappearance of the grandest power that man has yet subdued to his own use has even gained ground in later years among engineers, and we find Sir Frederick Bramwell, as long ago as at the York meeting of the British Association (1881), predicting that, unless some great improvement were made in the steam-engine, its days, for small powers at least, were numbered, and that another fifty years would see this wonderful agent and servant of mankind only in the museums, preserved as merely of antiquarian interest. Seven years later, at the Bath meeting, the same distinguished engineer signalizes his election to the presidency of the association by reiterating the same conviction.

In a recent article in the *Forum*, treating of "Steam and its Rivals," I have shown what are the principles involved in the

transformation and conversion of energy from the form of heat to that of mechanical energy in this class of motors, and have given my reasons for doubting the probability that any one of the numerous other available working fluids proposed as substitutes for steam will ever successfully displace that cheap, convenient, and efficient motor. What are the probabilities of the steam-engine soon seeing its "last days" may, perhaps, be best judged by tracing the development of that motor from its inception to its latest form, observing the method, extent, and direction of improvement in the past and at present, and comparing it in these respects with its anticipated rival, the gas-engine.

Before making this comparison it should be stated that the three essential conditions of economical operation of a heat-motor of whatever kind are: First, the possibility of securing so high a pressure in the working cylinder that the resistance of the machine itself shall become comparatively small and unimportant; secondly, that the working fluid shall have a power of expansion with sustained pressure in a maximum degree; and, thirdly, that it shall be competent to convert a maximum proportion of heat into mechanical energy, and thus to supply the demanded power at a minimum cost for fuel and operating expenses. Further than this, the machine must be reasonably safe, convenient of operation, and durable. It should, for many purposes, as for navigation, be compact, simple, powerful, and light of weight, and in many, in most, cases it should be of minimum cost per horse-power, as well as economical of operation.

It is now over a century since Erasmus Darwin, the grandfather of the great naturalist, published his "Botanic Garden," in which he wrote:

> "Soon shall thy arm, unconquered Steam, afar
> Drag the slow barge, or drive the rapid car;
> Or, on wide-waving wings expanded, bear
> The flying chariot through the fields of air."

This was at a time (1781) when the earliest of the great inventions of James Watt had hardly been conceived, and long before they were made generally known. The prediction was but little less remarkable than the famous stanzas of Homer:

> "We use nor Helm nor Helms-man. Our tall ships
> Have Souls, and plow with Reason up the deeps;
> All cities, Countries know, and where they list,
> Through billows glide, veiled in obscuring Mist;
> Nor fear they Rocks, nor Dangers on the way."

Pope's translation* furnishes the following rendering of Homer's prophecy:

> "So shalt thou instant reach the realm assigned,
> In wondrous ships, self-moved, instinct with mind;
> * * * * *
> Though clouds and darkness veil the encumbered sky,
> Fearless, through darkness and through clouds they fly.
> Though tempest rage, though rolls the swelling main,
> The seas may roll, the tempest swell in vain;
> E'en the stern god that o'er the waves presides,
> Safe as they pass and safe repass the tides,
> With fury burns; while, careless, they convey
> Promiscuous every guest to every bay."

The minds of the prophets, from the earliest times, were evidently fully prepared to look with confidence and faith to the appearance of the wonderful motor that first received its form from the genius of Watt.

The real inventor of the modern steam-engine, however, was, more correctly, Thomas Newcomen. It was he who first converted the old, wasteful, dangerous contrivances of Savery and his predecessors into a comparatively safe, and, even for the time, economical machine. Watt found this machine of Newcomen already in successful operation, and it continued in operation until after the death of Smeaton, the greatest of contemporary engineers. Watt made use of the Newcomen machine as the base of his own invention, and adding to the crude engine his separate condenser, introducing the steam-jacket, adopting better valve gearing, and making other improvements, he converted that engine into the modern steam-engine. The purpose of these more important changes was, as Watt himself expressed it, "to keep the cylinder as hot as the steam which entered it." The older engines wasted heat and steam enormously. As the piston moved backward and forward in the cylinder, under the alternate impulsion of the steam and the atmosphere, the motor fluid was first introduced to follow the piston and, displacing the air, to exert its pressure upon it, then to be condensed, forming a vacuum behind the piston, allowing the pressure of the air or of the steam, as the case might be, to act in turn. The condensation was effected in the Newcomen engine by the introduction of a jet of water into the cylinder, in the midst of the steam, thus at once condensing the steam and

* "Odyssey," Book VIII., p. 175.

cooling the cylinder down to the temperature of the water of condensation. The result of this operation was that, when the next charge of steam was introduced, the first action was the heating-up of the cylinder to the temperature of the steam itself by the condensation and waste of a corresponding amount of steam which otherwise might have been applied to the impulsion of the machine. This enormous waste was first observed and ameliorated by Watt, and the work of all great inventors improving the steam-engine, from his time to ours, has been mainly the reduction of wastes, partly by modifications of construction and partly by that gradual progress in the elevation of steam-pressures, in increasing the speed of the engine, and in making available a more complete expansion, which has attracted the attention of every intelligent observer of its advancement from that day to this.

The machine of Watt, in its most perfect state at the commencement of this century, was, at its best, a slowly-moving, cumbersome, wasteful, and feeble machine, as compared with the modern forms of engine familiar to us as the motors of our steamships, our railway trains, our factories, and our mills. To-day it represents the noblest product of the inventive genius of man. We may to-day say, more unreservedly than could Belidor:

> "VOILÀ LA PLUS MERVEILLEUSE DE TOUTES LES MACHINES ; le Mécanisme ressemble à celui des animaux. La chaleur est le principe de son mouvement ; il se fait dans ses différens tuyaux une circulation, comme celle du sang dans les veines, ayant des valvules qui s'ouvrent et se ferment à propos ; elles se nourrit, s'évacue d'elle même dans les temps réglés, et tire de son travail tout ce qu'il lui faut pour subsister."

Before we can judge with confidence whether this most wonderful of all the marvellous inventions of the mechanic is approaching its last days, it will be necessary to consider what is the nature of this energy-transforming machine ; what are its powers ; whence derived ; what its advantages and disadvantages, its merits and its defects ; what it has done, is doing, can do ; to what extent further growth and improvement seem to be possible; what seem to be the limits which are being approached ; where further improvement may probably cease ; when may we reasonably expect to see it reach those limits, and what may we anticipate to be the powers and characteristics of the finally perfected machine, when man's genius can no further go. We must also

inquire what are the characteristics of its presumed rival and in what respect are we to look for superiority, or a higher limit of perfection, as the end of the contest for superiority approaches.

Buried in the depths of the earth, distributed all over the globe, and in total quantity beyond the ability of the human mind to conceive, and almost beyond its power of computation, lie the skeletons of forests which covered the earth for, perhaps, millions of years during that early period called by the geologist the carboniferous. During a long interval of time the globe was covered with a warm, moist, misty atmosphere, rich in carbonic acid, the food of the vegetable kingdom, and its soil was kept warm and productive by the conjunction of the heat of its internal fires with the caloric received from the sun and held encaged by this atmosphere, which is known to have the property of permitting easy transmission of the rays of the sun to the earth, while strongly resisting their return into space. Under such circumstances, the growth of vegetation took place with a rapidity unknown even in the tropics to-day; the earth became covered with forests; forests grew on the relics of earlier vegetation; millions of square miles of soil were composed of the trunks, the branches, the leaves of tropical plants, the stems of gigantic ferns, the masses of enormous mosses; while the sea was clogged with marine vegetation the growth of which was stimulated by a steady and uniform warmth extending from the equator to the poles. Higher animal life could not exist amidst this atmosphere of mixed air and carbonic gases; but the lower forms swarmed throughout the world. Thus heat, moisture, and carbon-supplying compounds conspired to provide a wonderfully gigantic and rankly-growing vegetation, and the progress of ages saw the rise and the fall of measureless quantities of woody material, which was finally spread over the earth, to form, by later consolidation and by the elimination of volatile constitutents, those apparently inexhaustible stores of fuel now an essential element of human life and civilization. The partial decomposition of the animal and vegetable juices and fibre produced the petroleums and the unimagined quantities of compressed gases which are just coming into use for fuel and light in many parts of the country—a hitherto unsuspected reserve..

This process of production and storage of fuels of such strange variety of condition and composition is now known to have been

a system of reception and storage of a minute part of the energy, the work-power, that the sun and the subterraneous fires of the earth were lavishly and wastefully distributing in all directions into space. Every pound of the carbon thus stored away for the use of the human race in the millions of years succeeding the millions that should elapse before its appearance on the globe, is now known to hold in "potential" form, as the man of science puts it, 14,500 thermal units of heat, once active and kinetic in the sun or in the earth. Of this heat every 2,500 thermal units, or a trifle over, will measure the equivalent, each hour, of a horse-power; every pound of pure coal contains the equivalent, if burned in one hour, of about six horse-power; every ton of carbon burned per hour is the measure of over 13,000 horse-power. The coal-producing area of the world, so far as known, is about 400,000 square miles, of which about three-fourths is in the United States and one-fortieth in Great Britain. But Great Britain is estimated to possess 200,000,000,000 tons of fossil fuels. At the same rate, the United States possesses 4,000,000,000,000, and the world, we may presume, about 6,000,000,000,000 tons, allowing for as yet undiscovered deposits. This will last the human race, if we assume a rate of expenditure twice as great as to-day,—500,000,000 tons per annum,—for 12,000 years. At this rate of expenditure, it is the equivalent of about 15,000,000,000 horse-power for the world.

Measured by the periods of the geologist, obviously the human race is very rapidly using up its essential material of sustenance; quite as much so as if it had its food stored in a similar manner in the depths of the earth. Measured even by the time-gauge of the historian of civilization, or by the chronologies of the Egyptians and the Hindoos, the race has but little time to live on this earth, unless it can find, and promptly, means of economizing its stock of heat and available power, or unless some other resource, as yet unknown, is discovered by the man of science or by the inventor.

Most unfortunately, the facts of the case, as revealed by science, are that the best methods of utilization yet known to the world are enormously wasteful. Fortunately, if looked upon from the other side, there remains a margin for improvement and economy of very considerable magnitude, of which, it is believed, human genius will soon find ways of greatly availing itself. The

best heating apparatus of the day ordinarily wastes at least one-fourth of all the heat developed by the combustion of fuel; the best heat-engines of the day, whether steam or other, waste over four-fifths. Ordinary forms of heating apparatus and of heat-engine probably waste, on the average, not less than one-half and *nine-tenths,* respectively. Could these wastes be reduced to insignificant figures, the life of the race would be more than doubled; every ton of coal would heat, on the average, twice as long, or twice as much space; every steam-engine, on the average, would use but one-eighth as much coal, or less, or the fuel used for power would last eight times as long as now. But science shows that, if we must adhere to known methods of utilization, a sensible loss of heat must be submitted to, and a large waste of fuel in heat-engines, in whatever form, is inevitable. We are thus forced to the conclusion that either existing types must be improved much more effectively than now seems possible; or a new type of engine must be invented; or a new system of transformation of heat-energy into mechanical energy must be discovered, which shall not involve the now necessary and unavoidable thermodynamic loss, by converting the latent energy of fuels into some other form of natural energy, perhaps into electricity.

This latter is one of those obvious and seemingly possible improvements which the scientific men of the time are beginning to search for; it has been effected by nature, ages ago, in the firefly and the glow-worm, in the production of light, and in the whole animal economy in the production of heat and power. There seems no reason to assume that its discovery is always to remain beyond the reach of men of science.* But until that much-to-be-desired point is reached in the scientific progress of the race, it seems probable that we must depend upon the so-called heat-engines for the utilization of that inconceivable store of potential energy which lies dormant in our coal-beds, in our oil-fields, and in those ungauged reservoirs of "natural gas" upon which we are now drawing so prodigally and wastefully. Latent energy must be converted into the active form by chemical forces,

* The writer publicly called attention to this evident, but apparently previously unnoted, yet vitally important, matter as early as 1881. See his second President's Address to the American Society of Mechanical Engineers, November, 1881: Trans Am. Soc. M. E., 1881.

causing combination of oxygen with hydrogen and carbon and resulting in combustion; and the heat so produced must be transformed into mechanical energy and work by the, at best, wasteful operation of heat-engines.

"Heat-engines" are the machines devised by the engineer and the mechanic for the purpose of the conversion of all this stored energy of past ages, and of the once kinetic heat-energy of the universe, into mechanical power. All known forms—steam-engines, gas-engines, hot-air engines, æther-engines, whatever their class—exhibit certain common essential features: they depend for their power upon the production of heat by the combustion of a fuel, and transform the energy of molecular movement thus evolved into mechanical power and mass motion, through changes of pressure and volume effected in a "working fluid," as the steam, the gas, or the air which gives a name to the engine employed. In all of them, a mass of gas or vapor, or of a mixture of both, is caused to absorb a quantity of heat, and thus to take an accession of pressure, of temperature, or of both pressure and temperature, and of volume, expanding behind a piston which it drives by the excess of its pressure above that of the air, or the vapor in a condenser, on the opposite side, until, the stroke being completed, the unutilized stock of heat and of fluid is expelled.

Science shows that, in all such operations, it is impossible to transform a proportion of the heat stored in the working fluid, or communicated to it during this cycle of operations, greater than the proportion borne by the range of temperature worked through to the total absolute temperature of the working fluid at its maximum, measured down to the perfect zero of heat-motion, nearly four hundred degrees below the zero of Fahrenheit. In the best steam-engines this, to-day, represents the proportion of about two hundred to eight hundred; in the gas-engines something like twice this proportion. In other words, it is known, by scientific processes of unquestionable accuracy, that in the best of ordinary practice in steam-engineering, if it were possible to conduct the proposed operations in a perfect machine, incapable of wasting any portion of the heat or power by conduction, radiation, or friction, but one-fourth of all the heat-energy stored in the coal used in its furnace could be converted to useful purposes by transformation into mechanical power; and, similarly, the gas-engine has a maximum possible efficiency, as it is called,

of about one-third. These figures may be increased indefinitely by increasing the initial temperature of the fluid actuating the engine.

The actual performance of heat-engines falls short of these ideal efficiencies in proportion as they are subject to wastes of heat and of power due to their imperfections as structures or in operation. Perfect utilization of the heat from the fuel would give us a horse-power, in the steam-engine, through the consumption of about two and a half pounds of steam, or a quarter of a pound of good coal, per hour. Very few engines could, "theoretically," work on less than ten pounds of steam or one pound of fuel; the wastes usually bring the actual performance far short of this, and in the very best type of engine, these wastes often amount to about as much as the quantity actually required "theoretically." A gas-engine which should use but ten cubic feet of gas per hour and per horse-power actually demands, at best, twenty—ten for use thermodynamically, ten to supply wastes due to the fact that the machine has a working cylinder composed of metal, a substance capable of storage and of conduction of heat. That form of heat-engine which most completely reduces these wastes, other things being equal, will constitute the fittest, the surviving, form of heat-engine. That which permits the highest ideal efficiency and is least subject to such losses will ultimately outlive all competitors. It is asserted that it will be the gas-engine, not the steam-engine, which must be expected to do the work of the world in the end; since, as is thought, it is capable of working through the widest range of temperature, and offers the most promising outlook for reduction of internal wastes. That it must be one or the other of these forms of engine—or possibly the hot-air engine—is generally believed by scientific men and by engineers to be certain; since it is only these classes of machine which use as working fluids those which are at once readily available, of no cost, free from liability to special accident or to produce serious annoyance or injury to life, if liberated, and each, in its way, peculiarly well fitted for the storage and utilization of energy. Steam stores the most heat; air or the products of combustion of the gas-engine, which are essentially similar to air and largely composed of the elements of the atmosphere, permit the adoption of a wide range of temperature; steam gives

high pressures, and wastes but little power in driving its own mechanism; air or the gas, through the adoption of a wide range of temperature, gives high efficiency of thermo-dynamic transportation, but is loaded in larger proportion by the resistances of its machinery. That which ultimately can be made to work up at once to high temperature and to high pressures, and can be, at the same time, made to develop its powers in the smallest and lightest engine, will be the survivor in the competition, the winner in the race.

The whole history of the steam-engine has been a history of progressive amelioration of the wastes of the earlier and cruder machines, and of gradual increase in temperatures and pressures at which it has been worked. Watt's engines demanded one cubic foot (62½ pounds) of water and ten pounds of fuel, per horse-power and per hour; the best engines of the next generation required about five pounds of coal and forty pounds of steam; those of the period signalized by the successful introduction of the Sickels "cut-off" and of the Corliss engine, three pounds of coal and thirty pounds of feed-water, and the best engines of our time are claimed to work on one and a half pounds of fuel and fifteen pounds of steam, or less, per horse-power per hour; and even now we are expending 50 per cent. in what are judged to be avoidable wastes, and are consuming six times the mechanical equivalent of the heat-energy stored in our coal, in the process of transformation into power. The principles of its operation are, however, only now becoming generally and thoroughly understood by men of science and by engineers, and we may anticipate the approach, soon, to the practical limit of its improvement in the direction of reduced wastes of heat by conduction and by transfer without transformation. The limit of gain in range of working temperature remains an uncertain and conjectural matter.

The history of the hot-air and of the gas-engine is a similar story. Both have a history extending over about a century, as has the steam-engine of modern type. The gas-engine, taken as the more important of the two, required, in its earlier forms, about one hundred cubic feet of gas per horse-power per hour; by the middle of the century, it had come down to from fifty to seventy feet; ten years ago, to about thirty feet; and the best engines of our day consume about twenty feet, or a little less, of

the best gas, when of moderate size and power. As in the steam-engine, these improvements have been effected by changes which have resulted in the reduction of the wastes of the machine; the ideal thermodynamic requirements remaining substantially unchanged. The heat called for for thermodynamic transformation is as at first, nearly; but the losses by internal conduction and by external transmission through the thus far essential "water-jacket," required to prevent injury to the machine by its own internal fires, have been to this extent reduced. When, in both engines, if ever, these losses can be substantially evaded, the two machines will stand, so far as can now be seen, in about the relations above stated as those of the ideal machines.

The two machines have had, thus, pretty nearly the same length of life and opportunity to exhibit their capacities for useful work. What have they accomplished? Which has thus far been the more efficient servant of mankind? Which has done more and which is doing more for the world? Finally, which gives to-day the better evidence of capacity to do effectively and satisfactorily the work of the coming centuries, to utilize the more thoroughly the stored energies of those millions of millions of tons of coal still remaining in the depths of the earth?

The gas-engine, after years of struggle against natural and artificial obstacles, to-day successfully drives a few thousand small factories and does the work of an insignificant portion of the world's industries; it competes with steam here and there, where work of small magnitude is demanded; it is now and then effective for powers exceeding fifty horse-power. Its fuel is costly; its weight and bulk are considerable; it is sold in the market at high prices. The promise is that it may, if in time supplied with cheaper fuel, give higher efficiency and correspondingly extend its range of competition with steam; there is no reason, as yet, to believe that it can ever be expected to operate at a higher maximum or much lower minimum temperature, or to have a much wider range of working temperature; the reduction of its wastes to *nil*, hardly to be hoped for, would double its economy of fuel. Any great extension of its powers for unity of its weight is very uncertain. If we assume that it may, in time, double its efficiency and may have its weight reduced to one-half or one-third that now common, it may, perhaps, be taken as a fair estimate. This would give us a gas-engine using about a half-pound

of gas, or ten cubic feet, per horse-power per hour, and weighing, exclusive of the gas-generating apparatus, about two hundred and fifty pounds per horse-power. It is not anticipated that the steam-engine, as at present constituted, can ever consume as little as ten pounds of steam, or about one pound of coal, per horse-power per hour. It weighs, as a minimum, about fifty pounds per horse-power, including boiler. The cost of gas is to-day many times that of coal, weight for weight; it is not anticipated that it can ever be brought down to as little as twice the cost of the coal from which gas is necessarily made. It is not likely, apparently, that we can ever hope, therefore, to have a gas-engine that shall compete in cost of fuel with the steam-engine, where of equal powers; nor can we hope that it will ever, gas-producer included, nearly approach the small weight for equal powers that has already been attained by its rival—a weight which, it is expected, will in time be still further and greatly reduced in the steam-engine. The use of the gas-engine at sea or on the rail, the grandest and most extensive of the uses of the heat-engine, seems thus quite beyond reasonable expectation, even if competing with the steam-engine of to-day. Should ways of increasing the economy of working of the steam-engine be devised,—and we have no reason to presume that the days of invention and of scientific progress in that direction are past,—the gas-engine has still less chance in the competition.

The steam-engine, on the other hand, with but little longer period of actual growth, instead of being confined in its operation to the pigmy tasks measured by ten, twenty, or fifty horse-power, drives ten thousand tons of ship and freight, living and inanimate, across three thousand miles of sea, in face of the heaviest gales, indifferent to wave or storm or current; crossing the Atlantic in six days; attaining twenty miles an hour, the whole week through; exerting fifteen thousand horse-power continuously; doing the work that, if done by horses, would require a stable of 60,000 horses, weighing three times as much as the great ship and cargo altogether and demanding more space than could be found in fifty such ships. It does its work so cheaply that the burning of a copy of this magazine in its furnaces would afford sufficient power to transport a ton of freight five or eight miles, consuming, as it does, in the very best of recent ships, less than a pound and a half of fuel per horse-power per hour. Its weight is but two hundred pounds per horse-power,

and this is brought down in torpedo-boats and fast yachts to one-fourth that figure, but at the sacrifice of economy. On land, it draws a thousand tons of freight at a cost of a half-cent per ton per mile, bringing the wheat-fields of Dakota nearer the consumer in Boston, New York, or Philadelphia than were those of the Genesee valley at the date of its application to this task, but little more than a half-century ago. It spins across the continent in four days; it transports the traveller, with his bed, his table, his library, his stores, his wardrobe, a thousand miles, from New York to Chicago, in a single day; it alone still does the work about which it was first set by Watt a century ago, the raising of water from the depths of the earth that mines may continue to supply us with coal, with ores, with the precious metals; it drives all the spindles; it actuates every loom; it does the work of the world.

And who shall say that the steady progress of a century has reached its limit? Are we to presume that we may set a period to the victories of the mechanic, or assert that the genius of the inventor shall cease to be the main-spring of advance in our material civilization, the foundation of that prosperity on which culture must lay its most solid foundations? Can we see a limit to the improvement of the steam-engine more definitely than could the generation preceding Watt? It may well be doubted if the growth of this wonderful and indispensable servant of the race, more powerful than Aladdin's genius, has reached its end. On the contrary, every step made in the further advancement of the philosophy of the subject, every new discovery in science or in art, indicates that the limits of the development of this mightiest of the products of human constructive talent, this noblest work of the engineer, are set far ahead. By reducing the visible wastes of the contemporary machine, we can see that its efficiency may be nearly doubled; by increasing the range of temperatures through which it may be worked, its gain in economy may be indefinitely greater; by finding ways of utilizing its rejected—its necessarily rejected—heat, the engine being thermodynamically perfected, we may again make an enormous advance; by the steady increase of the speed of its piston, up to a limit quite beyond our present outlook, and far beyond our experience, we may gain in lightness and cost of production and of transportation, and thus in extent

of application, possibly even, in time, to the point of meeting the prediction of Darwin or of old Mother Shipton.

The engineer and the man of science see no reason to set a limit to the extent to which the wastes may be reduced ; none to the extension of the working range of temperatures—even to the point of superheating to temperatures limited only as those of the gas-engine are limited, by the resisting power of the materials of construction. They see no natural limit, in the near future, to the decrease of weight or of lost work in the machine itself. No one can yet say when or where the limit of improvement of the steam-engine is to be reached. Were a guess to be hazarded, it might, perhaps, be that we may see the steam-engine of the next generation consuming one pound of fuel per horse-power per hour; weighing twenty-five pounds per horse-power ; driving ships of twenty thousand tons or more at the rate of thirty or even forty miles an hour ; crossing the Atlantic in three or four days ; spanning the continent by flying trains in two days ; transporting machinery and cotton and woollen goods to San Francisco at a cost of three or four dollars a ton, and returning the grain and the fruits of the Pacific coast and of Mexico to feed and to comfort the poorest of our workers at prices that they may all afford to pay ; doing the work of the world far more cheaply and more universally than to-day; continually, and with still invisible limit, developing in power, applicability, and economy. It seems far more likely that the life of the race will ultimately be conserved, through those thousands of added years, by the steam-engine, improved by a hundred coming inventors, than by any other form of heat-engine.

But a time must come, nevertheless, when, the coals and the oil and the gas being substantially exhausted, the race must depend upon the steadily decreasing heat of the sun for its life and support. Then, perhaps, humanity may remember gratefully John Ericsson, the inventor of the "Sun Motor."

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